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RECEIVED 17 June 2025

ACCEPTED 11 August 2025

PUBLISHED 02 September 2025

CITATION

Lutomia CK, Ayuya OI, Yila JO,
Bomuhangi A and Nchanji EB (2025)
Gendered behavioral drivers in the adoption
and sustained use of improved common bean
varieties in Eastern Uganda.
Front. Sustain. Food Syst. 9:1648376.
doi: 10.3389/fsufs.2025.1648376

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Gendered behavioral drivers in the adoption and sustained use of improved common bean varieties in Eastern Uganda

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Understanding farmers' behavior is critical to designing effective training and extension services that increase access to and sustain the use of improved crop varieties. However, a critical gap remains in how to target behavioral change processes effectively. The study explored gender-specific behavioral drivers of access to and sustained use of high-quality common bean seeds in Eastern Uganda. An ordered logit model was used to analyse data collected from 323 common bean men and women farmers. Results indicate that women had greater access to and sustained use of improved common bean varieties. Men and women had equal access to information and training in improved common bean seeds but differed significantly in their perceptions of the benefits and drawbacks of the varieties. Regression estimates showed that farmer-to-farmer and peer learning, as well as the perceived net benefits of improved common bean varieties, increased both men's and women's access to and sustained use of improved varieties. Training significantly influenced women's seed access and use behavior, while access to information increased the probability of adoption and continued use among men. Men perceived that gender norms greatly influenced their decisions to adopt common bean varieties. These findings highlight the need for capacity building on the benefits of gender transformative approaches that address gender norms, information dissemination, farmer-to-farmer learning, on-farm experimentation to encourage sustained use of improved common bean varieties.

KEYWORDS

gender, seed access and use, seed adoption behavior, farmer-to-farmer learning, climate change, training and extension services

1 Introduction

Access to high-quality seed, defined as seed with high genetic and physical purity, germination capacity, viability, and vigour, and free from any seed-borne diseases and pests (Altuner, 2018), is fundamental to transforming agri-food systems in sub-Saharan Africa. It contributes to a range of outcomes, including higher yields, higher farmer incomes, greater resilience to climate shocks, enhanced food and nutrition security, and more sustainable agricultural practices (FAO, 2021; Quarshie et al., 2021). Seed systems in sub-Saharan Africa have focused on addressing limited capacities of both private and public seed sector players (Quarshie et al., 2021), with less emphasis on equitable access and seeds of improved bean varieties use. Despite developments in the seed sector, improved seeds are not reaching

small-scale producers at scale, and informal seed systems remain dominant (Sperling and McGuire, 2010; Walsh and Sperling, 2019). Women face the greatest disadvantages due to limited access to resources, educational barriers, restrictive social norms, inadequate infrastructure and markets access, and under-representation in decision-making seeds of improved bean varieties (Adam and Muindi, 2019; Kramer and Trachtman, 2024). These constraints often force women to reuse seeds or rely on older varieties.

Despite the growing gender research in seed systems, few studies have examined the behavioral factors that underpin adoption and sustained use of improved seeds. Existing research predominantly focuses on structural constraints such as credit, land, and extension access (Adam and Muindi, 2019; Namatovu, 2019). However, behavioral dimensions—such as risk perceptions, learning processes, cognitive biases, and adherence to social norm—are increasingly recognized as critical to adoption outcomes (Acheampong et al., 2023; Ha et al., 2024). Behavioral factors are relevant in climate-vulnerable farming systems, where adoption decisions influence both household resilience and long-term sustainability. For example, farmers' beliefs about performance a crop variety and peer influence can outweigh formal extension messages (Chaudhuri et al., 2021; Wale and Holm-Mueller, 2017). Yet, there is limited evidence on how these behavioral factors intersect with gender norms to influence continued seed use, particularly among women, who are primary bean cultivators in many sub-Saharan African communities. This study addressed this gap by examining gender-specific behavioral drivers of adoption and sustained use of improved bean varieties in Eastern Uganda. The objective was to contribute to gender-responsive and climate-resilient seed system interventions.

Over the last three decades, the Pan-Africa Bean Research Alliance (PABRA) has played a pivotal role in increasing the availability and visibility of improved bean varieties in Uganda and across sub-Saharan Africa. Specific gender interventions by PABRA are tailored capacity-building programs, gender-responsive demand-led breeding, women enterprise development, and community-based seed systems (PABRA, 2022). These efforts have strengthened availability and use of improved bean seeds and yielded positive economic outcomes (Justus et al., 2025). However, evaluations suggest that overreliance on externally facilitated programs can limit continuity once support is withdrawn (Nchanji et al., 2024). Consequently, Rubyogo et al. (2010) observed that the long-term sustainability of partnerships and demand-led models behavioral change adapt seed-use practices and reduce dependency on external support.

Common bean is an important food crop in Uganda, traditionally regarded as a women's crop (Nakazi et al., 2017). Women's involvement in bean production and marketing contributes to their economic empowerment and household food and nutrition security (NAADS, 2020). The crop is cultivated across diverse agroecologies, demonstrating its role in enhancing climate resilience. However, productivity gains are constrained by limited access to quality seeds and agricultural information, particularly among women farmers (Namatovu, 2019; Amuda et al., 2024). Adoption of improved bean seeds in Uganda remains low at 27%, with 23% adopting partially and only 4% fully adopting (FAO, 2014), despite the release of over 10 climate-smart, micro-nutrient-rich, and market-preferred varieties in recent decades. These patterns indicate on-going reliance on traditional seeds and inconsistent adoption behavior which have direct implications for both resilience and gender equity.

Understanding drivers of adoption behavior is therefore critical to addressing the unique constraints and needs of women bean farmers.

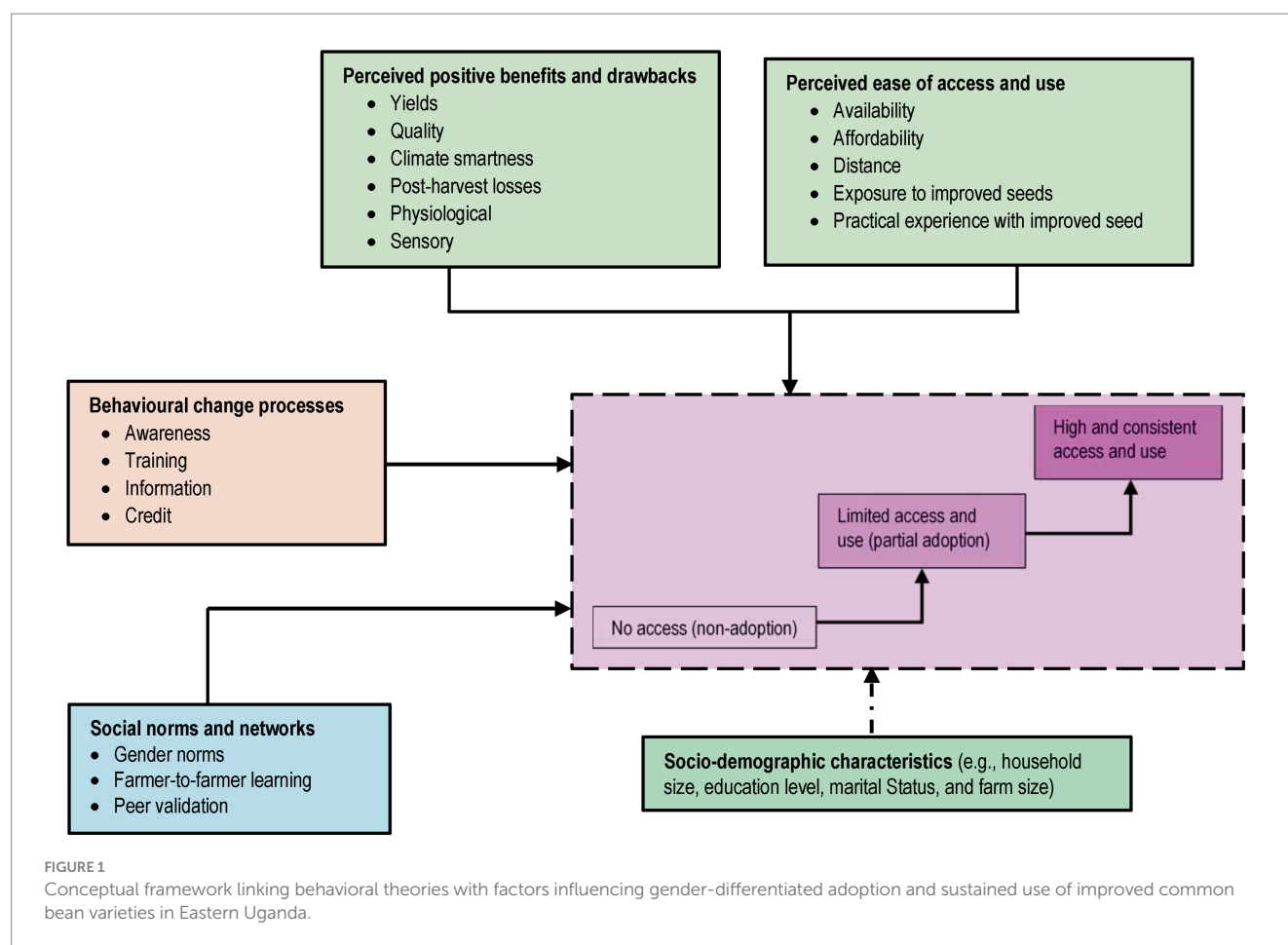
This article examines strategies to influence behaviors by focusing on tailored information and training, perceptions, gender norms, and social networks in sustaining adoption of seed of improved bean varieties. We address two research questions: (1) What behavioral factors influence women's adoption and sustained use of improved common bean seeds? (2) How do gender norms and social networks affect farmers' perceptions and behaviors toward adoption? We develop a conceptual framework that links behavioral change interventions, farmers' perceptions, and social norms with adoption pathways. The findings are intended to inform the design of gender-responsive interventions that promote equitable seed access, sustained seeds of improved bean varieties use of improved crop varieties and transform agri-food systems in ways that advance climate resilience and gender equality.

2 Conceptual framework

The study adopted a multi-theoretical approach to conceptualize access to and use of seeds of improved bean varieties. We combined the Technology Acceptance Model (TAM) (Davis, 1989; Marangunić and Granić, 2015), Theory of Planned Behavior (TPB) (Ajzen, 2011), Transtheoretical Model of Behavior (TTM) (Ha et al., 2024), Diffusion of Innovations, and gender and development concepts to link farmers' perceptions, social norms, and enabling conditions with adoption outcomes. These theoretical models were critical in explaining how farmers' perceptions (attitudes) and subjective norms influence farmers behaviors from non-adoption to partial adoption and then to sustained use of seeds of improved common bean varieties. Relationships drawn from these models are depicted in the conceptual framework shown in Figure 1.

From TAM, we measured farmers' perceived usefulness of improved common bean varieties in terms of multiple agronomic, market, and quality benefits and their negative perceptions (drawbacks). Together, perceived usefulness was measured as the net benefit score combining agronomic, market, and quality attributes. We also measured perceived ease of use (seed availability and affordability). TPB informed our inclusion of subjective norms (perceptions of gender norms and peer adoption) and perceived behavioral control (access to credit and training). Different stages of—non-adoption, partial adoption, and sustained use—were informed by the TTM. The Diffusion of Innovations was critical in informing the inclusion of exposure, trialability, and farmer-to-farmer learning into our conceptual framework (Chaudhuri et al., 2021; Kreft et al., 2023). Gender and development concepts highlighted the role of gender norms, resource access, and social networks in shaping adoption decisions. Grounded on these theoretical models, we anticipate that farmers positive perceptions of improved varieties of common beans would influence sustained adoption. Movement from partial to sustained use of improved common bean varieties was expected to be enabled by access to information, training, and credit (Acheampong et al., 2023), while social learning and peer validation were expected to reinforce adoption decisions.

We also incorporated control variables—socio-demographic characteristics such as gender, household size, education level, marital status, and farm size—to account for additional factors that may condition farmers' seed adoption behavior to contextualize the study



and position it within the gender and development literature. For instance, marital status and gender may influence intra-household decision-making dynamics in technology adoption (Mohapatra and Simon, 2017; Badstue et al., 2020a, 2020b), larger households might face greater resource constraints or have different priorities for technology adoption (Teklewold et al., 2013), educational may enhance awareness and understanding of the benefits of improved seed varieties (Khonje et al., 2018; Ullah et al., 2022), while land endowed farmers may have greater capacity to experiment new varieties (Kassie et al., 2015; Wu, 2022). These variables cover household and socio-economic contexts that may shape the adoption and sustained use of improved seed varieties.

3 Methodology

3.1 Area of study

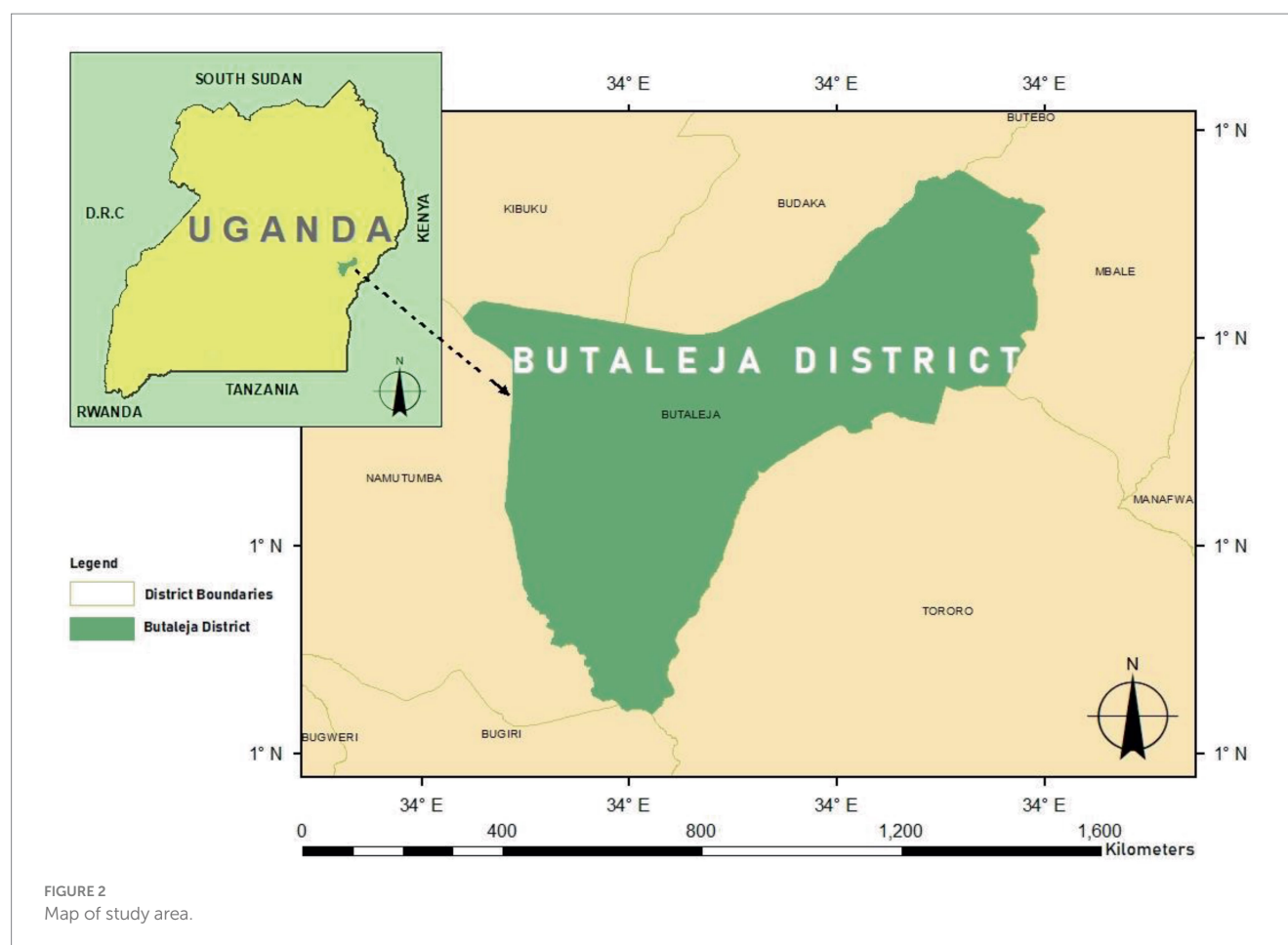
The study was conducted in Butaleja district, Eastern Uganda (Figure 2), a region with diverse agroecologies influencing agricultural practice. Rice production dominates in the Doho rice scheme, a wetland area, while upland areas are dominated by cereal (e.g., maize, sorghum, and millet), legumes (e.g., common bean, and groundnuts), and root and tuber crops (e.g., cassava, sweet potato, and bananas). About 95% of the rural communities in Butaleja are involved in both subsistence and commercial crop production. Women who are heavily

engaged in the cultivating and marketing of beans (Amuda et al., 2024). Common bean production in Butaleja is constrained limited seed access seed and quality persistence, reducing productivity and resilience of smallholders, particularly women and other marginalised farmers. Knowledge gaps, inadequate infrastructure, and socio-economic constraints further impede accessibility to seeds of improved bean varieties seeds of improved common bean varieties.

3.2 Sampling technique and data collection

A multi-stage sampling procedure was used to ensure that our sample was both representative of the target population in Butaleja District and within project resource and logistic constraints. In the first stage, Butaleja district was selected because it a beneficiary district of the CGIAR Seed Equal research initiative in Uganda. The Seed Equal Initiative aims to ensure equitable access to seed for women and other marginalized communities by supporting the delivery of seed of improved, climate-resilient, market-preferred and micro-nutrient rich varieties of priority crops.

In the second stage, two parishes—Naweyo and Nambale—were purposively selected due to their potential for common bean production. A total of 323 farmers were selected these parishes. Quantitative data were collected using a semi-structured survey questionnaire administered through face-to-face interviews with men and women, covering socio-economic characteristics, land access, production



practices, training and knowledge of improved varieties, seed use, asset ownership, decision-making roles, adoption factors, and financing.

The instrument was adapted from validated modules used in gender research by PABRA and customized to capture context-specific factors identified through preliminary consultations in Butaleja. Tool development involved expert review by seed systems experts in Uganda and PABRA gender scientist. The tool was pilot tested among 15 farmers in the field (excluded from the final sample) and refined for clarity, response categories, and translation accuracy in local dialects. Enumerators were trained with role plays and standardised probing procedures to ensure consistency. These processes were deliberate to ensure measurement reliability and content validity of the data collection tool.

3.3 Data analysis

The conceptual framework guided systematic aligning with the research questions. Farmers technology adoption behavior as reflected in the conceptual framework is influenced by individual perceptions (both drawbacks and positive benefits), perceived ease of access and use of improved common bean varieties (length of exposure to improved seeds, practical experience, distance, affordability, and availability), behavioral change processes (awareness, trainings. Information, and access to credit), and social norms and networks (perception of gender norms influence and farmer-to-farmer learning)

that was derived from 5-point Likert scale question that asked about level of agreement of the participant to the statement: To what extent do you believe gender norms influence your decision to adopt improved bean varieties? The question was consistent with norm perception studies (Mangheni et al., 2019). We included these variables in the analysis of the relationships between behavioral change interventions and farmers' perceptions with sustained use of seeds of improved bean varieties of improved common bean varieties.

The dependent variable was the status of access to and use of seeds of improved bean varieties, measured as a categorical variable: 0 = No use (non-adopters); 1 = Limited access and use (partial adoption); and 2 = High access to and continued use. We describe limited access and use as the use of seeds of improved bean varieties in one season, followed by subsequent discontinuation. In contrast, High access to and continued use are described as an initial adoption decision followed by continuous use of seeds of improved common bean varieties. It explains the dynamic progression through different stages of seed adoption to the maintenance stage when the farmer integrates high-quality seed as a consistent behavior every season, as described by the transtheoretical model of behavior change.

Subjective variables were operationalized through composite scoring. For instance, the net benefit score was calculated by aggregating farmer responses on 10 perceived attributes of improved common bean varieties—five representing benefits (e.g., yield, climate resilience, cooking quality, early maturity, and market value) and five representing drawbacks (e.g., cost, seed size, disease susceptibility, storage challenges,

and palatability). The net benefit score was calculated by aggregating farmer responses on 10 perceived attributes of improved common bean varieties. Five of the aggregated farmer responses represented the perceived benefits of improved common bean varieties: yields, climate resilience, cooking quality, early maturity, and market value. Negative score covered farmers' perceptions of the drawbacks of improved varieties of common beans—cost, seed size, disease susceptibility, storage challenges, and palatability. Farmers rated each attribute on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). The net score was obtained by subtracting the normalized sum of drawback scores from the benefit scores and then standardizing the result to a scale from −1 to +1 for comparability. The net benefit score reflected farmers' overall perceptions of improved seed varieties relative to local varieties.

We measured farmers' exposure to improved varieties by calculating the number of years since a farmer first heard about improved varieties. Practical experience with improved seed was measured as the duration of actual use of improved seeds. We asked farmers to report whether they knew farmers in their communities growing improved common bean varieties. This was used as a proxy for farmer-to-farmer learning and peer validation.

The outcome variable—status of access to and use of seeds of improved bean varieties—is an ordinal categorical variable for it reflects progression in adoption behavior that is consistent with the TTM. The ordered logit model was used to estimate the probability of the farmers being at or below each category (status of adoption) using cumulative logits for it accounts for the ordinal nature of the dependent variable. We used the Brant test to check whether the proportional odds assumption for the ordered logit model was met. The test statistic was not significant, and therefore, the standard ordered logit model was considered. Socio-demographic characteristics (e.g., household size, education level, marital status, and farm size) were included in the regression equation as control variables.

The ordered logit model can be represented mathematically as:

$$\log \frac{PY \leq j}{PY > j} = \alpha_j - \beta X$$

where y is the ordinal dependent variable (status of access to and use of seeds of improved bean varieties), j is the specific category or threshold of the outcome variable (0 = No use, 1 = Limited access and use, and 2 = High access to and continued use), $P(Y \leq j)$ is the cumulative probability of the outcome being at or below category j ,

α_j is the intercept (cutpoint) for category j , and β is the coefficient vector for the independent variables X as conceptualized in Section 2.

4 Results and discussion

4.1 Access to and use of seeds of improved bean varieties

The results in Table 1 show levels of access to and use behavior of improved common bean varieties by gender. Larger proportion of women (69%) than men (64%) consistently planted improved common bean varieties in the last two common bean production seasons. Almost 8% (9% of women and 8% of men) of the farmers are participating in a trial phase of improved common bean varieties. There were 28% of male farmers and 22% of female farmers who were non-adopters of improved common bean varieties (Table 1). In the right chart, half of both female and male farmers surveyed planted only one improved variety, while 25% of females and 17% of males planted varieties in the last two cropping seasons. Less than 4% of both men and women farmers had grown three or more varieties. Test statistics for adoption status ($\chi^2 = 1.660$, $p = 0.436$) and number of varieties grown ($\chi^2 = 4.707$, $p = 0.319$) were not statistically significant, implying gender may not be a major determinant in these specific improved seed use behaviors.

Farmers' behavior may differ even among users of improved seeds. Analysis presented in Table 2 captures this potential behavior. Partial adopters planted up to two varieties, with 85% planting improved varieties and 15% planting two varieties. A large proportion of both partial (77%) and consistent (63%) female adopters planted one variety in the last two cropping seasons. However, there was a greater diversification among consistent female adopters, with 34% and 4% growing two or more common bean varieties, compared to 22% of partial adopters who planted only one variety. All male partial adopters planted one variety while 68, 27, and 5% of male consistent growers planted one, two, and three varieties, respectively. The high proportions of single variety adoption among both partial and consistent adopters could indicate either preferences for one variety or constraints to multiple use of seeds of improved bean varieties. Although no significant gender differences were observed, the slightly higher diversification among female farmers may reflect gender differences in preferences due to a combination of socio-economic, cultural, risk perception and aversion, and seed access-related factors.

TABLE 1 Status of access to and use of improved common bean varieties by gender.

Variables	Total	Female	Male	p-value
Level of access to and use of seeds of improved bean varieties				0.436
No use	24.15	21.84	28.21	
Limited access and use	8.36	8.74	7.69	
High access and continued use	67.49	69.42	64.10	
Number of varieties grown				0.319
None (zero)	24.15	21.84	28.21	
One	50.77	50.49	51.28	
Two	22.29	25.24	17.09	
Three	2.48	1.94	3.42	
Four	0.31	0.49	0.00	

TABLE 2 Number of improved common bean varieties grown by adoption status and gender.

No of varieties	Pooled		Female		Male	
	Partial	Consistent	Partial	Consistent	Partial	Consistent
1	85.19	64.68	77.78	62.94	100	68.00
2	14.81	31.19	22.22	33.57		26.67
3		3.67		2.80		5.33
4		0.46		0.70		

TABLE 3 Descriptive statistics of independent variables related to farmers' social and behavioral characteristics by gender.

Variable	Total	Female	Male	Diff.
Awareness of improved varieties	47.68	46.6	49.57	−2.97
Training in improved varieties	17.03	15.05	20.51	−5.46
Information on improved varieties	64.71	64.08	65.81	−1.73
Net benefit score	0.19	0.15	0.26	−0.11**
Influence of gender norms	39.32	43.69	31.62	12.07**
Seed availability	87.62	90.29	82.91	7.38*
Seed affordability	84.83	84.47	85.47	−1.00
Access to credit (%)	35.29	39.81	27.35	12.46**
Distance to market	77.71	77.67	77.78	−0.11
Exposure to improved seed varieties information	15.46	14.59	16.96	−2.38*
Experience with improved seeds	13.08	12.16	14.74	−2.58*
Knows other farmers growing improved varieties	88.1	86.71	90.62	−3.91

** $p < 0.05$, * $p < 0.1$.

4.2 Independent variables

Table 3 summarizes variables related to farmers' social and behavioral characteristics disaggregated by gender. Less than half and one-fifth of both male and female farmers are aware of improved common bean varieties, and have received training in improved common bean varieties. While no significant gender differences emerged in awareness and training, the overall low exposure indicates structural constraints limiting the broader reach of seed information systems. The net benefit score was significantly higher ($p < 0.05$) for male farmers (0.26) compared to female farmers, suggesting gender differences in the perceived benefits of improved common bean varieties. Despite significant differences, the lower net benefit scores for both female and male farmers may be due to ambivalence rather than clear differences in perceived benefits of improved seeds.

Farmers' perceptions of the influence of gender norms on the adoption of improved common bean seeds were significantly ($p = 0.033$) higher among male farmers (44%) than female farmers (32%). This finding aligns with the with broader research on gender norms and agricultural technology adoption. Interpreted together with results in Figure 1 and Table 1, which showed a higher adoption rate among female farmers, findings suggest that men generally conform to the influence of gender norms (Mangheni et al., 2019; Nchanji et al., 2023). In Uganda, common bean is traditional considered a subsistence and women's crop (Nakazi et al., 2017), explaining lower use of improved varieties (Figure 1 and Table 1) and significantly higher perception that gender norms influence adoption of improved seeds among men.

Although the finding contrasts with the common narrative in literature that depicts women as disproportionately constrained by social norms, it supports the findings by Nchanji et al. (2023) that show men may face reverse bias in traditionally feminised crops, such as beans. However, Mangheni et al. (2019) caution against overgeneralizing, as the direction and intensity of normative influence can be highly context specific. This aligns with Wossen et al. (2017), emphasizing that gendered barriers to adoption are not uniformly experienced and may shift depending on the gendered value chains and cultural framing of the crop in question.

Most farmers believed that the availability and affordability of improved seeds influence their adoption, regardless of gender. At the same time, no significant gender difference was observed with respect to farmers' perceptions of the importance of the affordability of high-quality seed. The percentage of male (90%) farmers who perceived that availability was an important factor influencing adoption was marginally higher than the percentage (88%) of female farmers. Myeni and Moeletsi (2023) also found that unaffordability and unavailability of seed influenced the use of improved seeds in South Africa. Mwalongo et al. (2020) and Kramer and Trachtman (2024) also found that although men and women farmers' seed adoption decisions were influenced differently by several factors, their overall perception of affordability were similar. These findings underscore the importance of improvements in distribution networks not only to enhance availability but also to reduce transaction costs that increase the prices of seeds of improved common bean varieties.

The results in Table 2 also show that low percentages of both male (27%) and female (40%) farmers have access to credit. The percentage of

women with access to credit was significantly higher than men. This finding contradicts studies that have shown that women have limited access to credit facilities due to cultural and institutional barriers (Agier and Szafarz, 2013; FSD Uganda, 2021). This anomaly could be due to localized interventions such as group savings schemes or informal lending. Women's higher access to credit in the context of this study could be associated to their membership in savings groups or borrowing from informal sources due to institutional barriers that impede their access to formal sources. No significant difference ($p = 0.982$) was observed regarding female farmers' perceptions that distance to market matters in influencing the adoption of seeds of improved varieties. Similar results were reported by Baglan et al. (2020) and Amankwah (2023), who noted that the influence of distance to the market on the adoption of improved crop varieties did not significantly differ by gender.

Furthermore, males had marginally higher exposure to information about seeds of improved common bean varieties and experience with improved seeds than female farmers. This highlights the importance of inclusive extension services and information delivery systems in ensuring that both men and women have access to improved seeds. There was no significant gender difference regarding whether farmers knew other farmers planting seeds of improved crop varieties in their locality. This could potentially imply an equal social network effect on the adoption behavior of female and male farmers.

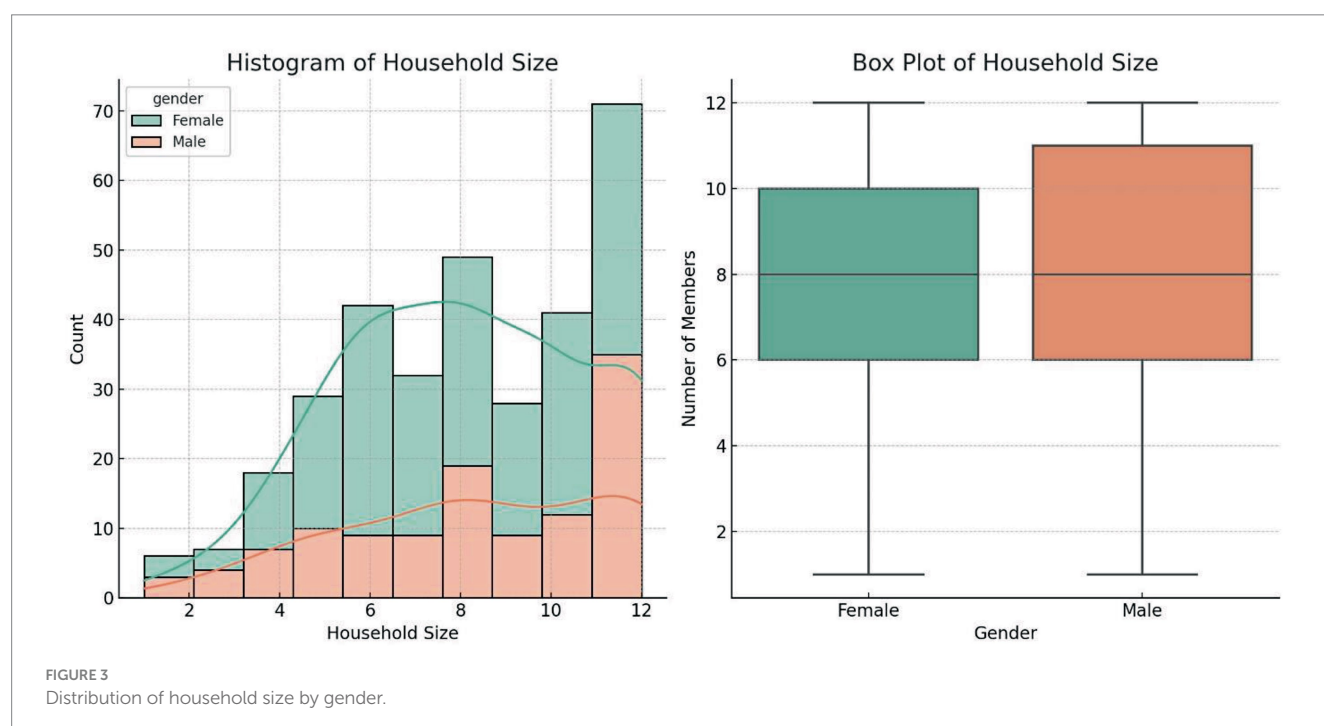
4.3 Socioeconomic variables

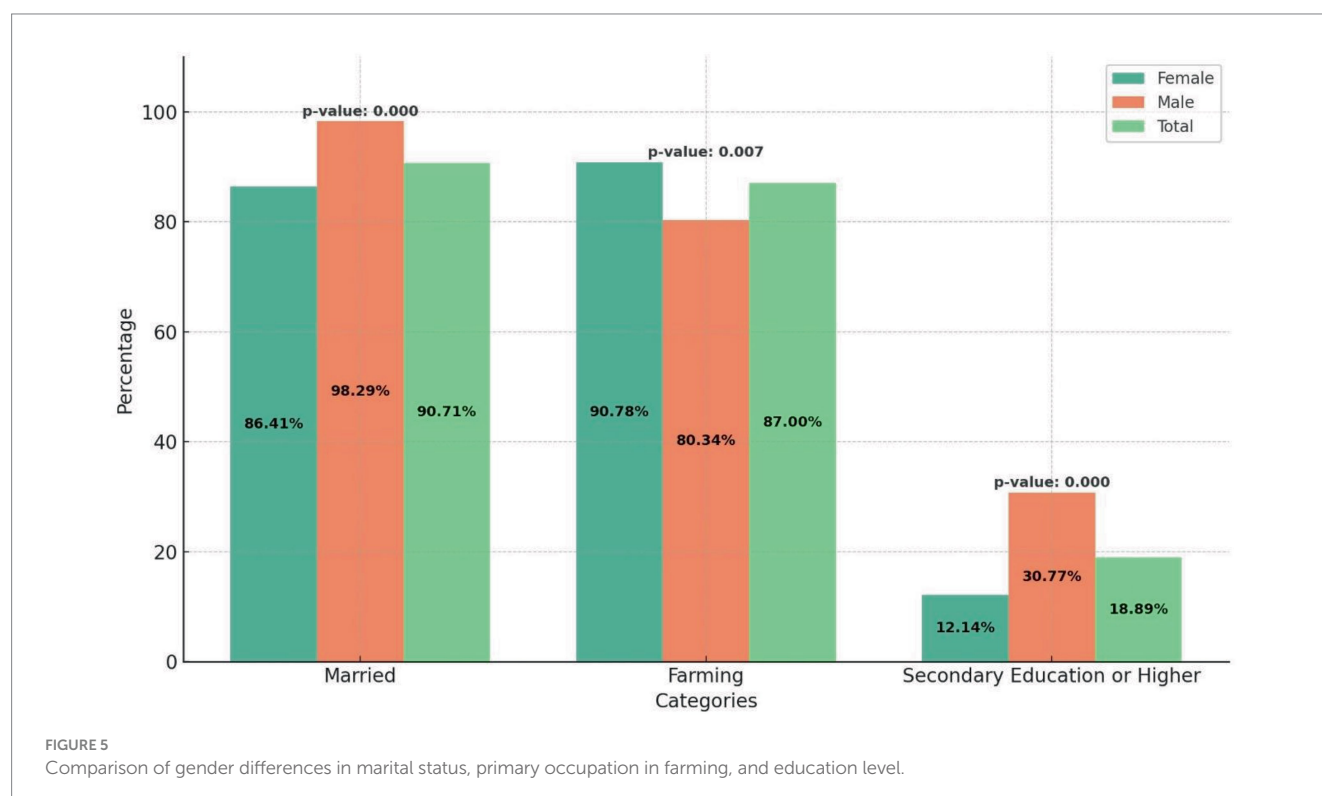
The histogram on the left of Figure 3 shows that female-headed households tend to have more members at the extremes (both small and large sizes). There is a notable peak at the larger household sizes for females (around 12 members), while male-headed households have a more uniform distribution across different sizes. On the right-hand side of Figure 3, the boxplot shows median household sizes reported by female and male farmers that are almost identical.

However, there is slightly more variability in household size reported by male farmers. The high distribution of household sizes at both the lower and upper tails among women and the greater variability in household size distribution among male farmers reveal subtle differences in marital status and possible extended family living arrangements. This could have possible implications for decision-making dynamics and resource allocation within households.

The distribution of farm size owned by households is presented in Figure 4. The histogram on the left side of Figure 4 shows that the distribution of farm size owned by households is skewed towards small landholdings for both male and female farmers. However, while male farmers had a slightly broader distribution, females showed a noticeable concentration at smaller land sizes. The boxplot on the right side of Figure 4 confirms this observation as indicated in the lower median farm size compared to males. The boxplot also reveals a higher presence and range of outliers for male farmers, suggesting a possible larger landholding among males than women. These results could be linked to economic, gender roles, social or legal factors.

Socio-demographic factors that could influence farmers' behavior and adoption patterns of high-quality seed are presented in Figure 5. Generally, farmers had low educational attainment, as indicated by the fact that only 18% of surveyed farmers had achieved secondary education or higher. However, the percentage (31%) of male farmers who attained secondary education or higher was significantly higher than the proportion of female farmers (12%). Regardless of gender, most surveyed farmers were married (91%) and had farming as the main occupation (87%). A significantly higher proportion of males (98%) than females (86%) were married. However, a significantly higher percentage of female farmers (91%) reported farming as their main occupation compared to males (80%). The gender gap in education and the associated influence of marital status and primary occupation of women may interact with individual behaviors, perceptions, priorities, and constraints that influence the adoption of high-quality seed.





4.4 Econometric results

Table 4 presents ordered logit regression estimates of farmers' access to and use of high-quality common bean seeds. The dependent variable in the regression model was farmers' access to and use of high-quality common bean seeds. Six variables in the full model (unseparated regression) had significant effects on

farmers' seed use behavior. Five and four variables were significant in the separated female and male regression models, albeit at different significance levels. Two variables—net benefit perceptions of improved common and farmers' knowledge of other farmers growing improved varieties—underscore the importance of these variables in driving farmers' access to and use of high-quality seed.

TABLE 4 Ordered logit regression estimates of farmers access and use of high-quality common bean seeds.

Variable	Full		Female		Male	
	Coeff.	Std. error	Coeff.	Std. error	Coeff.	Std. error
Awareness of improved varieties	−0.641	0.428	−0.275	0.580	−0.789	0.704
Training in improved varieties	0.565	0.540	2.236*	1.247	−1.147	1.520
Information of high-quality seed	1.423***	0.459	1.077	0.674	1.728**	0.853
Net benefit of improved varieties	2.185***	0.501	2.518***	0.916	2.814***	0.930
Gender norms perception	0.379	0.439	0.234	0.560	1.353	0.831
Seed unavailability	−1.289**	0.637	−0.900	0.837	−0.768	1.150
Seed affordability	−0.214	0.656	0.279	0.639	−1.658	1.076
Access to credit	0.347	0.444	0.347	0.600	0.330	1.122
Distance to market	−1.274**	0.548	−0.850	0.725	−1.980**	0.996
Gender of farmer	−0.602	0.409				
Exposure to improved seed varieties information	−0.008	0.023	−0.015	0.033	−0.034	0.049
Experience with improved seeds	−0.021	0.024	−0.050*	0.029	0.041	0.060
Knows other farmers growing improved varieties	2.765***	0.583	2.144***	0.836	4.104***	0.991
Household size	−0.074*	0.081	−0.036	0.101	−0.239	0.186
Farm size	0.198	0.183	0.367*	0.773	0.203	0.396
Secondary education or higher	0.161	0.524	−0.233	0.850	1.498	1.282
Farming as main occupation	0.509	0.617	1.333	0.736	−0.471	0.817
Marital status (married)	0.017	0.680	0.046	0.780	−10.808	2.151

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Regardless of gender, farmers with a high net benefit perception of the advantages of seeds of improved bean varieties over local varieties had a higher probability of having sustained access to and use of improved seeds. These results demonstrate that farmers with favourable perceptions and attitudes toward improved seeds are strongly swayed not only to overcome ambivalent behavior (partial adoption) but also to move towards consistent adoption and use of seeds of improved bean varieties on a continuous basis. This highlights the influence of farmers' perceived benefits of high-quality seed over local varieties on the initial decision to adopt and to continue using improved varieties. This result aligns with the findings of [Wale and Holm-Mueller \(2017\)](#), [Ntawuruhunga et al. \(2020\)](#), and [Meshesha et al. \(2022\)](#) on the role of farmer perceptions on adoption behaviors. Specifically, [Wale and Holm-Mueller \(2017\)](#) found that positive perception of the benefits of improved varieties influenced the replacement of local seeds with seeds of improved bean varieties and the loss of traditional crop varieties in Ethiopia. However, [Wossen et al. \(2017\)](#) noted that positive perceptions alone may not always lead to adoption if broader enabling environments, including market access, input availability, and institutional support, are weak. For instance, in some cases, even farmers with positive attitudes may revert to traditional varieties due to inconsistent seed supply.

Farmers' knowledge of farmers growing improved varieties also had a significantly strong influence on the likelihood of high and consistent access to and use of seeds of improved bean varieties. The effect was significantly strong across three models. Being aware of or knowing farmers growing improved common bean varieties may have facilitated shared experiences, exerted

peer influence, or allowed verification of the observed benefits of improved varieties. Peer observations likely reduced uncertainty about improved varieties and facilitated learning about available seeds, which in turn encouraged adoption, as well as the sustained use of seeds of improved bean varieties. This demonstrates the crucial role of social influence in behavioral change among farmers. This finding is sufficiently documented in literature. For example, [Kaliba et al. \(2020\)](#) reported that the presence of farmers in a village where research activities are high, in this case, farmers planting improved common bean varieties, increased the propensity and intensity of use among farmers in Tanzania. Nevertheless, recent work by [Spielman et al. \(2021\)](#) cautions that peer effects may not always positively catalyse behavioral change and adoption, especially in contexts where trust in peer networks is low or misinformation spreads.

Furthermore, the ordered logistic results in [Table 4](#) show that training significantly increased the propensity of female farmers to access and use seeds of improved bean varieties but had no significant effect in the full and male models. In contrast, access to information had a strong and moderate positive, yet significant, effect in the full and male models, respectively. These findings confirm gendered asymmetries in the uptake of information and training. For women, training has a greater impact, likely due to lower baseline knowledge and systemic access barriers ([Puskur, 2021](#); [Kramer and Trachtman, 2024](#)). It highlights the need for gender-responsive training programs to overcome these barriers and influence the behavior of female farmers. However, contrary to some studies that report training as uniformly beneficial (e.g., [Wossen et al., 2017](#)), we observe no effect among men, possibly

due to saturation or a mismatch between the training content and their needs. Furthermore, some studies suggest that the effectiveness of training may be overstated when structural constraints persist. Ragasa et al. (2013) found that gender-neutral training interventions do not always result in increased adoption even after women's exposure due to their failure to address time poverty, mobility, and caregiving responsibilities that constrain women's participation.

Availability of seeds and distance to markets are closely linked. In Table 4, the perception that seed unavailability and distance to market constrain access to and use of seeds of improved common bean varieties, as expected, had a significantly negative effect on farmers' having higher access to and use of seeds of improved bean varieties in the full model. Notice that only the distance to market was negative and statistically significant in the male model. Although results from the full model reveal the importance of market proximity and overcoming logistical challenges—reduction of transaction costs—to enhance access to high-quality seed, the significance of distance in male model could reflect that men are more likely to be highly involved in marketing activities or purchasing of inputs compared to females due to their control over monetary resources. Conversely and somewhat surprisingly, seed availability or distance to market were not significant in the female model, possibly because female farmers face more pressing constraints (e.g., mobility, limited resources, time availability due to childcare and domestic chores, and weak power relations) that overshadow the effects of seed availability or distance to market. These findings highlight the importance of a dual gender-sensitive strategy that addresses both supply-side and demand-side constraints to seed access and continued use.

The duration of actual experience with improved seeds (negative coefficient in the female model), household size (negative coefficient in the full model), and farm size (positive coefficient in the female model) had marginal influences on farmers' propensity to access and consistently use seeds of improved bean varieties. This implies that more years of planting improved varieties resulted in a lower probability of adoption and consistent access to and use of improved seeds. This counterintuitive relationship could be explained by the unsatisfactory performance of seeds under local conditions due to climate change, changes in women's preferences over time, or inadequate external support, which, in the long term, outweigh the benefits of seeds of improved bean varieties (Grigorieva et al., 2023). The negative association between household size and access to and use of seeds of improved bean varieties suggests that large households are less likely to have consistent access to and use of seeds, possibly due to financial constraints. The less pronounced effects of household size in gender separated regression could be due to variances in household size for female households and counterbalance of resources in male households. Farm size increased the likelihood of female adoption and consistent use of improved seed varieties, suggesting that resource endowments for women lead to greater decision-making autonomy in adoption or offer opportunities for women to take calculated risks by adopting new seed varieties (Oyawole et al., 2021).

The findings have direct policy and programmatic implications. The significant association between net benefit perceptions and sustained use of seeds of improved common bean varieties suggest that extension services and seed delivery

programs should prioritize field days and localized on-farm demonstrations to showcase yield, quality, and climate-resilience advantages of improved varieties. The strong influence of peer learning on adoption and continued use of seeds of improved bean varieties point to the need for investment in farmer-to-farmer extension models. Extension system in Uganda could consider supporting community seed producer groups and local champions who can validate new varieties. Third, the gender-differentiated effects of training and information access highlight the importance of designing women-focused training programs. This suggest having flexible training schedules to reach time-constrained women farmers. Fourth, the negative impact of distance to market in the male model reinforces the need for policy interventions (e.g., community-based agro-dealers, farmer cooperative networks, community seed banks) that bring seed distribution points closer to farmers or improve rural transport infrastructure.

Our findings also indicate that intersecting factors such as farm size and household size marginally shaped adoption behaviors. Land access, particularly secure tenure for women, may encourage longer-term investments in improved varieties, whereas small or shared plots may discourage such investments, not only due to limited land area to cultivate the beans but also due to decision-making power is held by spouses, adult males within households, or extended family members when the plots are shared. Another significant variable—household size indicates that large-sized households may face greater competition over resources, leading to de-prioritization of investment on common bean or limiting consistent seed purchase and use.

5 Conclusion

Analysis of the influence of behavioral change processes indicates that access to information and training in improved seeds positively influenced the chances of male and female farmers moving from initial adoption to continued use of seeds of improved varieties of beans, respectively. While these results reveal the importance of training and information on influencing the behavioral change process, the effects are distinct for male and female farmers. Women need hands-on instructions or demonstrations on how to use the improved seeds effectively but highlights the role of information dissemination in supporting transitioning from initial adoption to sustained use of seeds of improved varieties. Capacity building and training for women and provision of information to enhance farmers' access to extension materials should be emphasized. Digital platforms and information dissemination and training events should be leveraged to enable learning and support continued.

The study also found that sustained use of high-quality common bean seeds was significantly influenced by farmers' balancing of the benefits and drawbacks of improved varieties. This variable was significant for both men and women demonstrating the importance of active promotion and demonstration of tangible benefits of improved varieties to all farmers. This can be achieved through effective communication by extension services, agricultural programs, and seed suppliers. The communications should showcase advantages of improved varieties vis-à-vis local

varieties. Another key finding in relation to the first research question was social network effect on access to and continued use of seeds of improved bean varieties. This finding points to the role of farmer-to-farmer extension and peer learning on overcoming uncertainties over high-quality seed of improved varieties. It finding underscores the need for on-farm experimentation to demonstrate the superior characteristics of improved common bean varieties.

In relation to the second research question, men perceived that gender norms greatly influenced adoption of improved common bean varieties. In the context of areas of study, this could imply that men considered common beans as a women's crop, and therefore, this social expectation could potentially affect male farmers' decision to invest in improved seeds. The finding calls for challenging gender norms that limit men's engagement with crops like common beans, incentivizing male farmers to invest in seeds of improved bean varieties, and addressing gender norms in seed delivery. Beyond social norms, intersectional results point the need for extension and seed systems practitioners to go beyond "women" definition and consider them as a heterogeneous group in their program design. Interventions should seek to address the varied constraints that may limit women's active participation in seed system intervention by considering the role of power dynamics, resource control, and social position.

This study deepens the understanding of effective ways of integrating gender equality in seed access by targeting specific behavioral drivers to promote adoption and continued use of seeds of improved bean varieties. While findings are valuable to seed systems practitioners, the analysis did not directly include variables that measure intra-household dynamics (e.g., decision-making power, processes, and patterns) that could influence seed use. Secondly, the analysis relied on retrospective reporting of seed use, participation in training and other variables, which may have potentially introduced recall bias. Additionally, farmers' perceptions of seeds local or improved bean varieties may have been subjective for social desirability. Thirdly, finding from Butaleja district may not be fully generalizable to other regions despite its agroecological and institutional diversity. Future research should aim to fill these gaps through methodological approaches that integrate detailed intra-household analysis, validate self-reported measures, and compare results across multiple regions.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

This study's ethical review and approval were waived since it was conducted by a government entity. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

CL: Methodology, Data curation, Writing – review & editing, Validation, Writing – original draft. OA: Writing – review & editing, Formal analysis, Writing – original draft, Methodology. JY: Writing – original draft, Conceptualization, Writing – review & editing, Investigation. AB: Conceptualization, Writing – review & editing, Writing – original draft. EN: Conceptualization, Investigation, Writing – review & editing, Funding acquisition, Writing – original draft, Validation.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. This study reflects work conducted under Work Package 6 of the CGAIR SeedEqual Initiatives, which is coordinated by the International Rice Research Institute (IRRI) and the Alliance of Bioversity International and CIAT. We want to thank all funders who support this research through their contributions to the CGIAR Trust Fund: www.cgiar.org/funders. The work is being continued under the inclusive delivery arm of the Breeding for Tomorrow science program.

Acknowledgments

We thank the seed producer groups, NGOs, seed companies, and NARS for providing data and coordinating data collection.

Conflict of interest

OI was employed by Afridev Economic Consulting Limited.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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